

Site-specific details of the recovery actions for vernal pool fairy shrimp populations in Oregon will be identified as part of a recovery plan for species of the upper Rogue River Valley, which is currently in preparation at our Roseburg Field Office. The Rogue River Valley recovery plan will develop an integrated, ecosystem-based strategy for recovery of vernal pool fairy shrimp and two endangered plant species that are endemic to the area, within the context of the broader recovery strategy identified in this Recovery Plan for Vernal Pool Ecosystems of California and Southern Oregon.

## **5. VERNAL POOL TADPOLE SHRIMP (*LEPIDURUS PACKARDI*)**

### **a. Description and Taxonomy**

***Taxonomy.***—The vernal pool tadpole shrimp was initially described by Simon (1886) and named *Lepidurus packardi*. Linder (1952) maintained *L. packardi* as a valid species. However, in a review of the order Notostraca, Longhurst (1955) reduced this and 18 other species to subspecies of *L. apus* based primarily on the lack of apparent geographic boundaries between *L. apus* and *L. packardi* populations. Lynch (1972) resurrected *L. packardi* to full species status based on further examination of specimens. This is the currently accepted taxonomic status of the vernal pool tadpole shrimp. Recent genetic analysis indicates *L. packardi* is a valid species (King and Hanner 1998).

***Description and Identification.***—Vernal pool tadpole shrimp, like other members of the Order Notostraca, are known as living fossils because they have changed little in appearance over roughly the last 2 million years, and resemble species found in the fossil record (Longhurst 1955, King and Hanner 1998). Vernal pool tadpole shrimp are distinguished by a large, shield-like carapace, or shell, that covers the anterior half of their body. Vernal pool tadpole shrimp have 30 to 35 pairs of phyllopods, a segmented abdomen, paired cercopods or tail-like appendages, and fused eyes. Mature vernal pool tadpole shrimp range in size from 15 to 86 millimeters (0.6 to 3.3 inches) in length.

Vernal pool tadpole shrimp and other species in the Order Notostraca have remained generally similar in appearance for hundreds of millions of years (Longhurst 1955). However, individuals often vary greatly in appearance, making classification and identification of species difficult (Gurney 1924, Linder 1952, Longhurst 1955, King and Hanner 1998). Recent genetic studies (King and Hanner 1998) may provide the basis for relating genetically detected differences to morphological variation, potentially allowing for the development of a classification key to the genus. Species in the genus *Lepidurus* can be distinguished from members of the similar looking genus *Triops* by the presence of a supra-anal plate between their cercopods, which is lacking in *Triops*. Two

other species of *Lepidurus* are found in California. One, the cryptic tadpole shrimp (*Lepidurus cryptus*), has recently been described (Rogers 2001). This species cannot be differentiated from the vernal pool tadpole shrimp by appearance, but the two species are genetically distinct (King and Hanner 1998, Rogers 2001). The cryptic tadpole shrimp occurs in the Great Basin and intermountain regions of northern California and southern and eastern Oregon, whereas the vernal pool tadpole shrimp occurs in the Central Valley, Delta, and east San Francisco Bay area (Rogers 2001). The cryptic tadpole shrimp is not known to occur within the range of the vernal pool tadpole shrimp as described in the listing rule (U.S. Fish and Wildlife Service 1994a). The other species, *Lepidurus lemmoni*, was described by Holmes in 1894 (Holmes 1894). This species is found in alkali playas high in calcium salts in California in the Mojave Desert in Inyo, Kern, San Bernardino, and Riverside Counties, in the Great Basin in Lassen, Modoc, and Siskiyou Counties, and also in Oregon, but does not co-occur with *L. packardii* (Rogers 2001, C. Rogers *in litt.* 2005). *Lepidurus lemmoni* is distinguished from *L. packardii* by having more than 50 leg pairs (vs. less than 40 in *L. packardii*), and the nuchal organ being placed behind the eyes (vs. between the eyes as in all other *Lepidurus*).

#### **b. Historical and Current Distribution**

**Historical Distribution.**—King *et al.* (1996) suggested that vernal pool tadpole shrimp probably evolved in the Central Valley of California after colonizing large inland lakes during the Pliocene and Pleistocene, approximately 2 million years ago. From the end of the Pleistocene until the mid-1800s, the Central Valley still contained extensive seasonal wetlands, sometimes covering the entire valley (Oakeshott 1978). Holland (1978) estimated that roughly 1,600,000 hectares (4,000,000 acres) of vernal pool habitat existed in the Central Valley during pre-agricultural times. Historically the vernal pool tadpole shrimp was probably distributed over most of these vernal pool habitats. However, surveys in southern portions of California have never revealed vernal pool tadpole shrimp populations, and the species probably did not occur historically outside of the Central Valley and Central Coast regions (**Figure II-38**).

**Current Distribution.**—The vernal pool tadpole shrimp is currently distributed across the Central Valley of California and in the San Francisco Bay area. The species' distribution has been greatly reduced from historical times as a result of widespread destruction and degradation of its vernal pool habitat. Vernal pool habitats in the Central Valley now represent only about 25 percent of their former area, and remaining habitats are considerably more fragmented and isolated than during historical times (Holland 1998). Vernal pool tadpole shrimp are uncommon even where vernal pool habitats occur. Helm (1998) found vernal pool tadpole shrimp in only 17 percent of vernal pools sampled

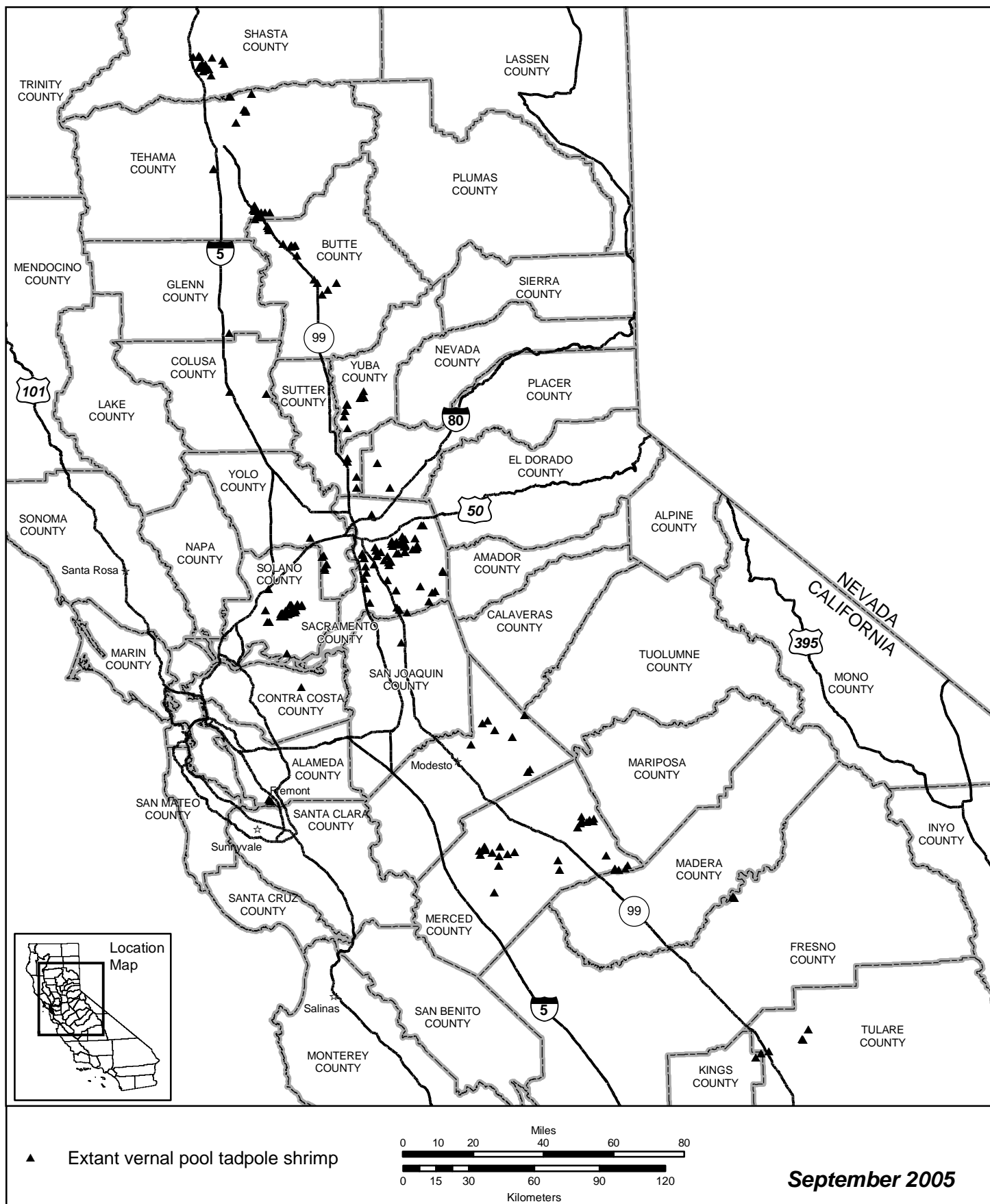


Figure II-38. Distribution of vernal pool tadpole shrimp (*Lepidurus packardii*).

across 27 counties, and Sugnet (1993) found this species at only 11 percent of 3,092 locations. In the Northwestern Sacramento Vernal Pool Region, vernal pool tadpole shrimp are found at the Stillwater Plains and in the vicinity of Redding in Shasta County. In the Northeastern Sacramento Vernal Pool Region, vernal pool tadpole shrimp have been documented on private land in the vicinity of Chico in Butte County and in Tehama County at the Vina Plains Preserve, the Dales Lake Ecological Reserve, and on Caltrans land. The largest concentration of vernal pool tadpole shrimp occurrences are found in the Southeastern Sacramento Vernal Pool Region, where the species occurs on a number of public and private lands in Sacramento County. Vernal pool tadpole shrimp are also known from a few locations in Yuba and Placer Counties, including Beale Air Force Base. In the Solano-Colusa Vernal Pool Region the vernal pool tadpole shrimp occurs in the vicinity of Jepson Prairie, Travis Air Force Base, and near Montezuma in Solano County and on the Sacramento National Wildlife Refuge in Glenn County. In the San Joaquin Vernal Pool Region, vernal pool tadpole shrimp are known from the Grasslands Ecological Area and private land in Merced County and from single locations in Tulare and Kings Counties. In the Southern Sierra Foothills region, the species occurs at the Stone Corral Ecological Preserve in Tulare County, on ranchlands in eastern Merced County, at the Big Table Mountain Preserve in Fresno County, and at a few locations in Stanislaus County. In the Central Coast Vernal Pool Region, the vernal pool tadpole shrimp is found on the San Francisco National Wildlife Refuge and private land in Alameda County.

### **c. Life History and Habitat**

***Life History.***—Although the vernal pool tadpole shrimp is adapted to survive in seasonally available habitat, the species has a relatively long life span compared to other vernal pool crustaceans. Helm (1998) found that the vernal pool tadpole shrimp lived significantly longer than any other species observed under the same conditions except the California fairy shrimp. Vernal pool tadpole shrimp continue growing throughout their lives, periodically molting their shells. These shells can often be found in vernal pools where vernal pool tadpole shrimp occur. Helm (1998) found that vernal pool tadpole shrimp took a minimum of 25 days to mature and the mean age at first reproduction was 54 days. Other researchers have observed that vernal pool tadpole shrimp generally take between 3 and 4 weeks to mature (Ahl 1991, King *et al.* 1996). Ahl (1991) found that reproduction did not begin until individuals were larger than 10 millimeters (0.4 inch) in carapace length. Variation in growth and maturation rates may be a result of differences in water temperature, which strongly influences the growth rates of aquatic invertebrates.

Vernal pool tadpole shrimp have relatively high reproductive rates. Ahl (1991) found that fecundity increases with body size. Large females, greater than 20 millimeters (0.8 inch) carapace length, could deposit as many as 6 clutches, ranging from 32 to 61 eggs per clutch, in a single wet season. Vernal pool tadpole shrimp may be hermaphroditic (Longhurst 1955, Lynch 1966, C. Rogers *in litt.* 2001), and sex ratios can vary (Ahl 1991, Sassaman 1991), perhaps in response to changes in water temperature.

After winter rains fill their vernal pool habitats, dormant vernal pool tadpole shrimp cysts may hatch in as little as 4 days (Ahl 1991, Rogers *in litt.* 2001). Additional cysts produced by adult tadpole shrimp during the wet season may hatch without going through a dormant period (Ahl 1991). Vernal pool tadpole shrimp emerge from their cysts as metanauplii, a stage which lasts for 1.5 to 2 hours. Then they molt into a larval form resembling the adult. Multiple hatching within the same wet season allows vernal pool tadpole shrimp to persist within vernal pools as long as these habitats remain inundated, sometimes for 6 months or more (Ahl 1991, Gallagher 1996, Helm 1998). Vernal pool tadpole shrimp hatching is temperature dependent. Optimal hatching occurs between 10 to 15 degrees Celsius (50 to 59 degrees Fahrenheit), with hatching rates becoming significantly lower at temperatures above 20 degrees Celsius (68 degrees Fahrenheit) (Ahl 1991).

**Habitat.**—Vernal pool tadpole shrimp occur in a wide variety of ephemeral wetland habitats (Helm 1998). The species has been collected in vernal pools ranging from 2 to 356,253 square meters (6.5 square feet to 88 acres) in surface area (Helm 1998). Some of these vernal pools may be too small to remain inundated for the entire life cycle of the tadpole shrimp, but the vernal pool tadpole shrimp may be able tolerate temporary drying conditions (Helm 1998). Vernal pool tadpole shrimp have been found in pools with water temperatures ranging from 10 degrees Celsius (50 degrees Fahrenheit) to 29 degrees Celsius (84 degrees Fahrenheit) and pH ranging from 6.2 to 8.5 (Syrdahl 1993, King 1996). However, vernal pools exhibit daily and seasonal fluctuations in pH, temperature, dissolved oxygen, and other water chemistry characteristics (Syrdahl 1993, Scholnick 1995, Wiggins 1995, Keeley 1998). Determining the vernal pool tadpole shrimp's habitat requirements is not possible based on anecdotal evidence, and the tolerances of this species to specific environmental conditions have yet to be determined. Although the vernal pool tadpole shrimp is found on a variety of geologic formations and soil types, Helm (1998) found that over 50 percent of vernal pool tadpole shrimp occurrences were on High Terrace landforms and Redding and Corning soils. Platenkamp (1998) found that vernal pool tadpole shrimp presence differed significantly between geomorphic surfaces at Beale Air Force Base, and was most likely to be found on the Riverbank formation.

**Population Structure.**—King *et al.* (1996) studied genetic variation among vernal pool tadpole shrimp populations at 20 different sites in the Central Valley. They found that 96 percent of the genetic variation measured was due to differences between sites. This result corresponds with the findings of other researchers that vernal pool crustaceans have low rates of gene flow between separated sites, between 0.02 and 2.61 individuals between sites per generation. The low rate of exchange between vernal pool tadpole shrimp populations is probably as a result of the spatial isolation of their habitats and their reliance on passive dispersal mechanisms. However, King *et al.* (1996) also found that gene flow between pools within the same vernal pool complex is much higher, between 0.5 and 14.4 individuals per generation. This finding indicates that vernal pool tadpole shrimp populations, like most vernal pool crustacean populations, are defined by vernal pool complexes and not by individual vernal pools.

Based on genetic differences, King *et al.* (1996) separated vernal pool tadpole shrimp populations into two distinct groups. One group comprised animals inhabiting the floor of the Central Valley, near the Sacramento and San Joaquin Rivers. The other group contained vernal pool tadpole shrimp from sites along the eastern margin of the valley. King *et al.* (1996) concluded that these two groups may have diverged because cyst dispersal by overland flooding recently connected these populations on the valley floor. Populations on the eastern margin of the valley likely experienced less frequent dispersal events, probably through different mechanisms such as migratory birds. King *et al.* (1996) also found that populations in eastern Merced County, in the vicinity of the Flying M Ranch and the proposed University of California Merced campus, were very different from all other populations studied. These researchers concluded, particularly because it is found on very ancient soils, that this group may have been isolated from other populations very early, and further suggested that this population may be a separate species.

#### **d. Reasons for Decline and Threats to Survival**

Most species addressed in this recovery plan are threatened by similar factors because they occupy the same vernal pool ecosystems. These general threats, faced by all the covered species, are discussed in greater detail in the Introduction section of this recovery plan. Additional, specific threats to vernal pool tadpole shrimp are described below.

The California Natural Diversity Database (2003) lists 17 occurrences of vernal pool tadpole shrimp as threatened by development. An additional 16 occurrences are reported as threatened by various agricultural conversions. The species is threatened by the encroachment of nonnative annual grasses on the San Francisco

Bay National Wildlife Refuge in the Central Coast region, and by urban development where it is known to occur on private land in Alameda County. In the Northeastern Sacramento Valley region, most of the known occurrences of the vernal pool fairy shrimp are on Caltrans rights of way where they continue to be threatened by road improvement projects related to general urban growth. In addition, the species is known to have been parasitized by flukes (Trematoda) of an undetermined species at the Vina Plains, Tehama County (Ahl 1991). The gonads of both sexes were greatly reduced in size and their body cavities were filled with many young flukes (metacercariae). Ahl (1991) thus concluded that parasitic castration was the major limiting factor affecting reproduction of the vernal pool tadpole shrimp at the Vina Plains. In the Northwestern Sacramento Valley Vernal Pool Region, the vernal pool tadpole shrimp is threatened by development on the few sites on private land where it is known to occur. In the Southeastern Sacramento Vernal Pool Region, extant populations of vernal pool tadpole shrimp are threatened by continued extensive urban development.

In the San Joaquin Vernal Pool Region, the species is threatened by development on private land. In the Solano-Colusa region, the species is threatened by urbanization on private lands.

In the Southern Sierra Foothills Vernal Pool Region, the species is threatened by development of the proposed University of California, Merced campus, which will likely contribute to significant growth in the region, resulting in additional loss of vernal pool crustacean habitat. Populations on the Stone Corral Ecological Reserve may be threatened by pesticide drift from adjacent farmlands.

#### **e. Conservation Efforts**

On September 19, 1994, the final rule to list the vernal pool tadpole shrimp as endangered was published in the *Federal Register* (U.S. Fish and Wildlife Service 1994a). In 2005, critical habitat was designated for vernal pool tadpole shrimp and several other vernal pool species in *Final Designation of Critical Habitat for Four Vernal Pool Crustaceans and Eleven Vernal Pool Plants in California and Southern Oregon; Evaluation of Economic Exclusions From August 2003 Final Designation; Final Rule* (U.S. Fish and Wildlife Service 2005).

Although conservation efforts have been taken for vernal pool ecosystems in general, very few actions have been taken specifically to benefit the vernal pool tadpole shrimp. An example of one of these actions is the implementation of a grazing program at the Stone Corral Ecological Reserve for the benefit of vernal pool crustaceans. The results of the monitoring program are being monitored by California Department of Fish and Game staff (J. Vance, pers comm. 2005).